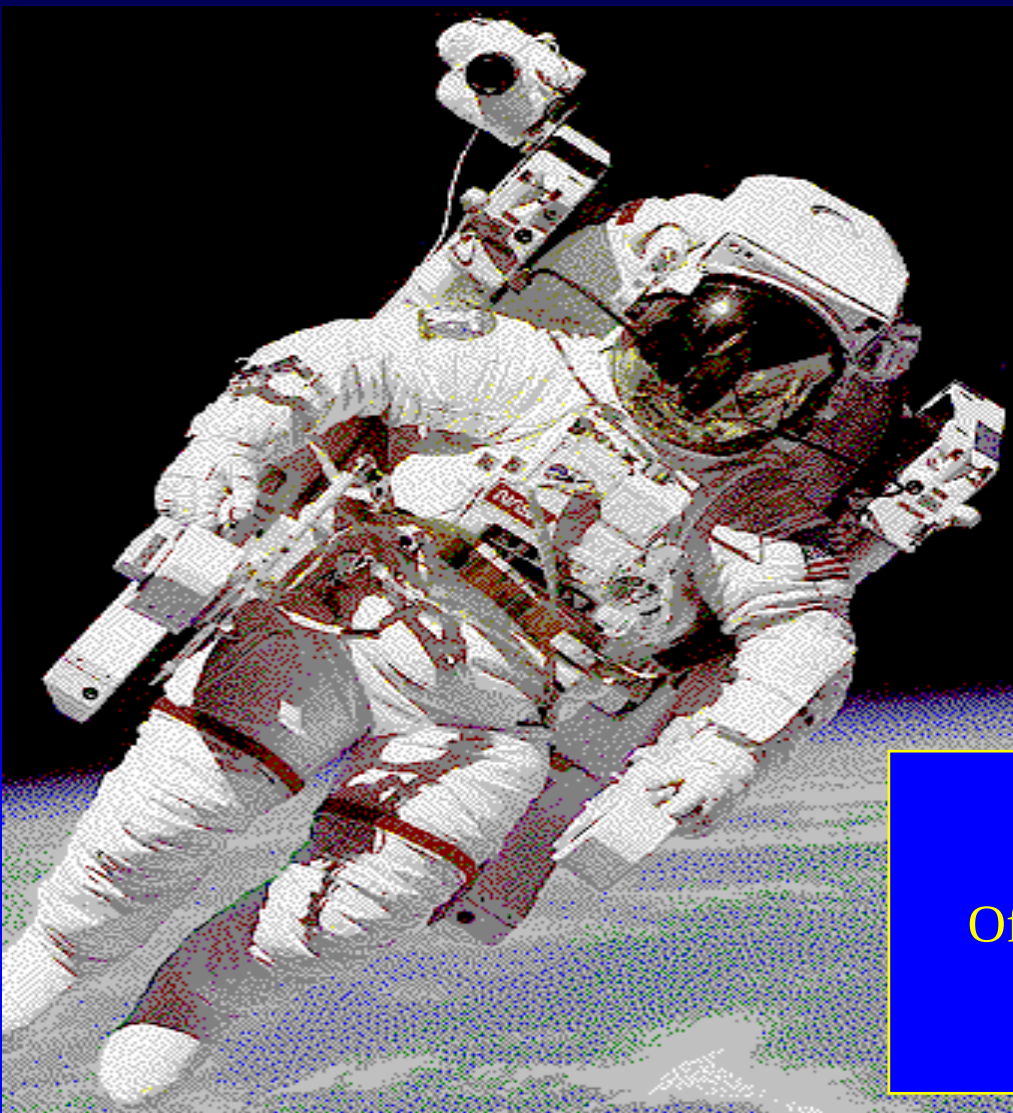
Nuclear Launch Safety Approval



Presentation to the
PRA Information
Exchange
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Nuclear Launch Safety Approval

- NASA has launched nuclear materials into space from early in the “Space Age”
- The goal of the launch approval process is to understand the risks associated with the launch of nuclear materials
- The US Government is internationally liable for it’s spacecrafts
- The launch approval decision-makers need to understand that the risk does not pose excessive harm to the US population or others around the world
- Space launches are items of high public interest and NASA must be ready to respond to concerns from the media, the public and around the world.

Mission Success Starts with Safety!

Large Nuclear Sources Launched in the past 40+ years

# Launches	Project	# RTGs	Date	Application	Inventory per launch (Ci)
5	Transit	5	’61-’62	Navigation	25k
2	Nimbus	4	’68-’69	Meteorological	34k
6	Apollo	6	’69-’72	Lunar Surface	44k
2	Pioneer	8	’72-’73	Planetary Flybys	91k
1	Transit	1	’72	Navigation	25k
2	Viking	4	’75	Mars Surface	41k
1	LES 8/9	4	’76	Communications	288k
2	Voyager	6	’77	Planetary Flybys	220k
1	Galileo	2	’89	Jupiter Exploration	268k
1	Ulysses	1	’90	Solar Observations	134k
1	Cassini	3	‘97	Saturn Exploration	400k

’96: Mars Pathfinder (90 Ci) and ’03: Mars Exploration Rover (265 Ci @ 2 launches)

’06 Pluto (1 RTG)

PRAXI Discussions

- During this session we will have 2 areas of discussion
  - Special Requirements and needs for PRAs to understand the added risks of Nuclear Systems
  - Special Requirements and needs for PRAs to support the launching of nuclear materials into space (Nuclear Launch Safety Approval)

Requirements and Needs for PRAs for Ground Based Nuclear Systems

Requirements and Needs for PRAs for Launching of Nuclear Systems into Space

Rules/Tools/Treaties/Agreements

1967 United Nations Treaty on Space Exploration

- Articles 1 thru 6:
  - International Cooperation
  - Peaceful use ONLY (no space Nuclear weapons)
- Article 7:

  Launching nation is internationally liable
- Article 8:

  Launching nation remains owner of satellite

U.N. Resolution 47/68

- Preamble:
  - Perform safety assessment, including PRA, to reduce risk
  - Resolution applies to space nuclear electric power sources used for non-propulsive purposes*
- Principle 3: Guidelines and Criteria for Safe Use
  - General goals for radiation protection and nuclear safety
    - Principal limit of 1 mili-Sv in a year — lifetime average
    - Maximum dose of 5 mili-Sv in a year for any given year
  - Accidents with low-probability and serious consequences are excepted
  - Ensure low probabilities through system design

* Return of operating reactor from was Mars not envisioned

Principle 3 (Continued)

- Reactors may operate:
  - In low-earth orbits if sent to high orbits* afterward,
  - In sufficiently high orbits * , or
  - On interplanetary missions
- Use only highly enriched Uranium 235 as fuel
- Induce criticality only on orbit or beyond
- Use design and construction to ensure subcriticality during all possible launch events
- Use highly reliable operational system to ensure disposal

* High enough to allow radioactive decay before reentry

Presidential Directive/ National Security Council Memorandum – 25 (PD/NSC-25)

- Requirements for scientific or technological experiments with possible large-scale adverse environmental effects and launch of nuclear space systems into space
- Requirements:
  - Presidential approval is required for the launch of spacecraft utilizing radioactive power sources
  - The Head of the Sponsoring Agency must request Presidential approval through the Office of Science and Technology Policy (OSTP)
  - Director, OSTP may grant launch approval or defer a launch decision to the President
  - An Interagency Nuclear Safety Review Panel (INSRP) comprising of DoD, DOE, NASA, EPA and U.S.NRC personnel must prepare a nuclear safety evaluation report

NASA Nuclear Safety Launch Approval

- Single NASA Point of Contact for

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- PD/NSC-25 calls for use of IAEA, Safety Series Number 6 Table 1 for determination of risk categorization using the A_2 normalization value
- NASA Policy Guidance (NPG) 8715.3 delineates requirements
- To determine Mission A_2 multiple use:

$$Mission\,A_2 = \sum_{sources} \left(\frac{\text{Quantity}}{\text{Isotope A}_2} \right)$$

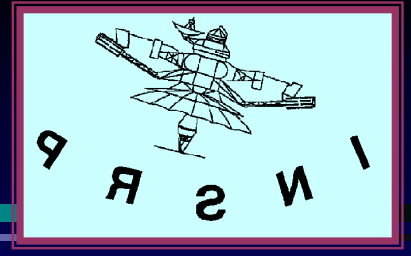
Risk Analysis Needed for Nuclear Safety Launch Approval

Total Mission A_2	NASA HQ Notified in Writing	Notified before launch	Risk Analysis	Risk Study Review	OSTP Notified	Nuclear Safety Launch Approval Grantor
$0 < \Sigma(A_2) < 0.001$	Yes	> 1 month	none	Coordinator	not notified	Coordinator
$0.001 < \Sigma(A_2) < 10$	Yes	~ 3 months	statement of ALARA	Coordinator	in quarterly repoort	Coordinator
$10 < \Sigma(A_2) < 100$	Yes	~6 months	white paper safety analysis	Coordinator	in quarterly report	AA for OSMA
$100 < \Sigma(A_2) < 1000$	Yes	~ 1 year	Safety Analysis Summary (SAS)	Coordinator with external review	via NASA Administrator	NASA Administrator
$1000 < \Sigma(A_2)$	Yes	> 3 years	Full Safety Analysis Report (SAR)	INSRP produces Safety Evaluation Report (SER)	via NASA Administrator	Executive Office of the President (OSTP)

Why an INSRP

- The INSRP is an Independent Assessment of the work done by the DOE and the Mission Program/Project Office.
- For Cassini Mission, once the SER was released, may comments from public interest groups on the credibility of the SAR disappeared.

An INSRP is ...



- Ad-hoc for the empanelled mission.
- Empanelled by NASA Administrator for NASA Missions or Head of Agency Sponsoring the mission when $$$ begin (about launch-4 years)
- Members required: DoD, DOE, EPA, and NASA with an NRC Tech Rep
- INSRP members, Tech Reps and consultants MUST be independent of Program
- Recent missions cost for the INSRPs was borne by Agencies, future INSRPs need to be paid for by Program Sponsor Agency.
- Provides Safety Evaluation Report to NASA Administrator and OSTP
- Dissolves after mission cancelled or after launch when NO chance of mission return to earth (in writing from empanelling Agency Head)

NOTE: OSTP is involved with each INSRP to ensure objectivity, independence and completeness

The Goal of the INSRP Process

- To review and summarize the risk of the nuclear material on the general public for the launch approval decision makers
- The output MUST be
  - complete
  - accurate
  - defensible
- INSRP's Customers include:
  - Secretaries of Defense and Energy, the Administrators of NASA and EPA, the NRC Commissioners, …
  - The White House
  - The American People

Traditional Documentation

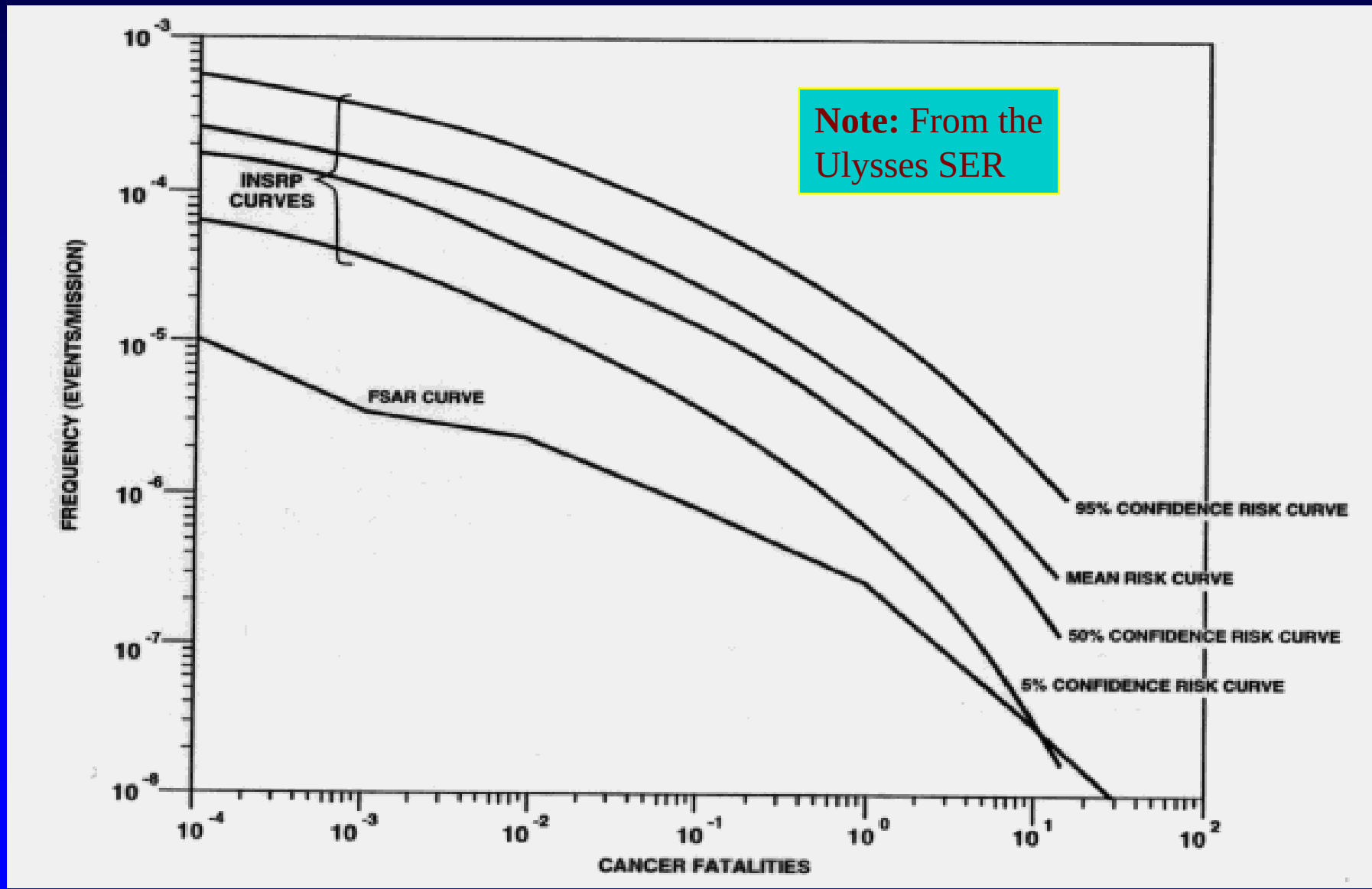
- Launch Approval process is based on 40 years of experience.
- 3 Safety analysis reports (SAR) have been the norm
  - Preliminary SAR — issued soon after design concept is selected (L-3 years)
  - Updated SAR — issued as soon as practical after the design freeze
  - Final SAR — needed by INSRP about 1 year before the launch
- INSRP provides feedback to the program after review of the PSAR & USAR
- INSRP uses the FSAR to generate the Safety Evaluation Report
- SAR/SER meets DoD/DOE/NASA/EPA/NRC requirement for internal agency reviews and is briefed to agency heads & OSTP

SER does NOT contain a recommendation to launch or not to launch

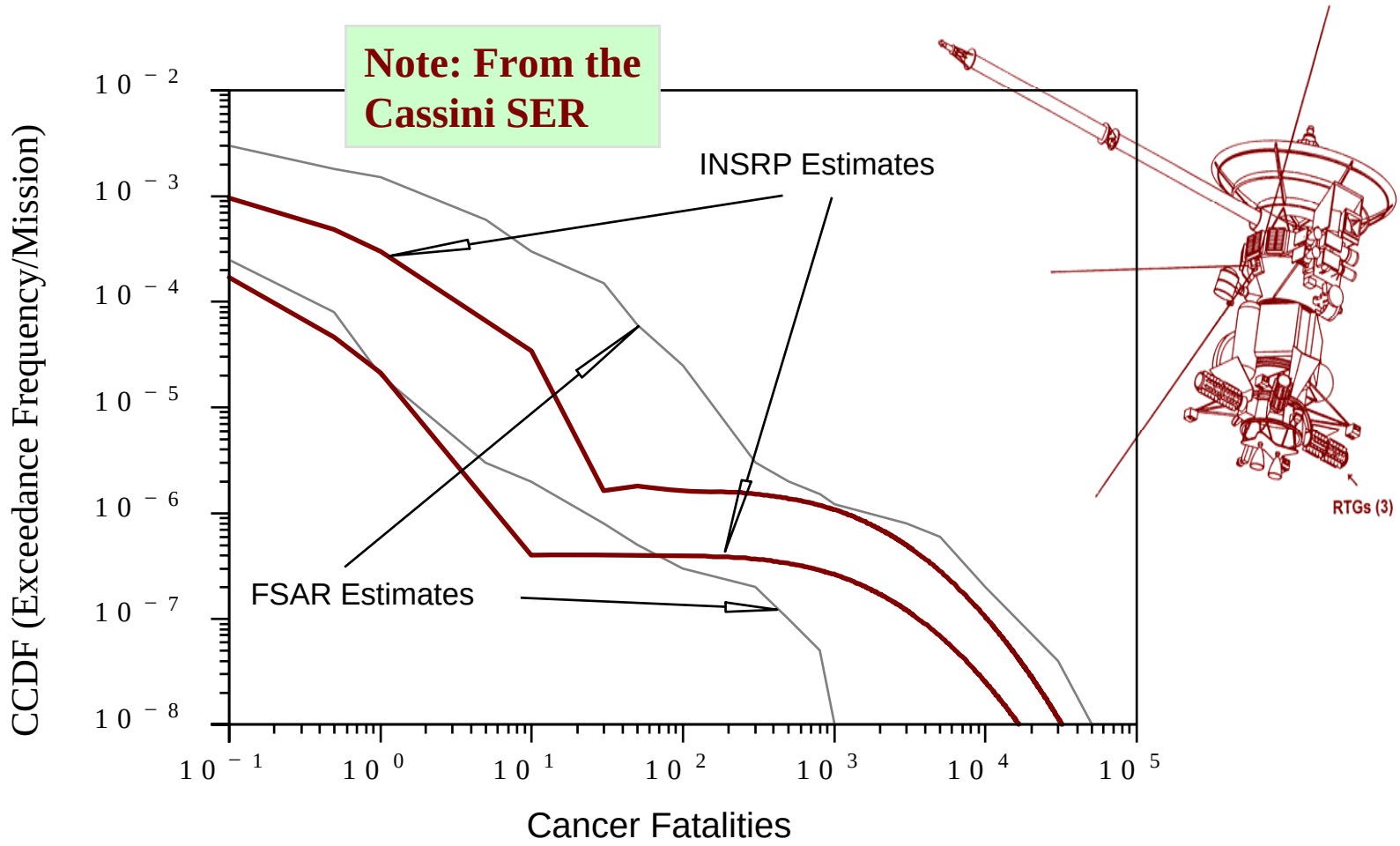
Types of Environments Considered

- Prelaunch, launch, and ascent phases
- Explosion overpressure
  - Projectile impact
  - Land or water impact
  - Liquid propellant fire
  - Solid propellant fire
  - Sequential combination of the above
- Orbit and/or flight trajectory phases
  - Reentry
  - Land or water impact
  - Collisions in space (meteoroids, space debris)
  - Post impact environment (land or water)
  - Reentry upon return from space (gravity assist, return from Moon, ...)
- Meteorological particle transport
- Potential resulting health effects and areas of contamination

Ulysses Mission Risk Curves



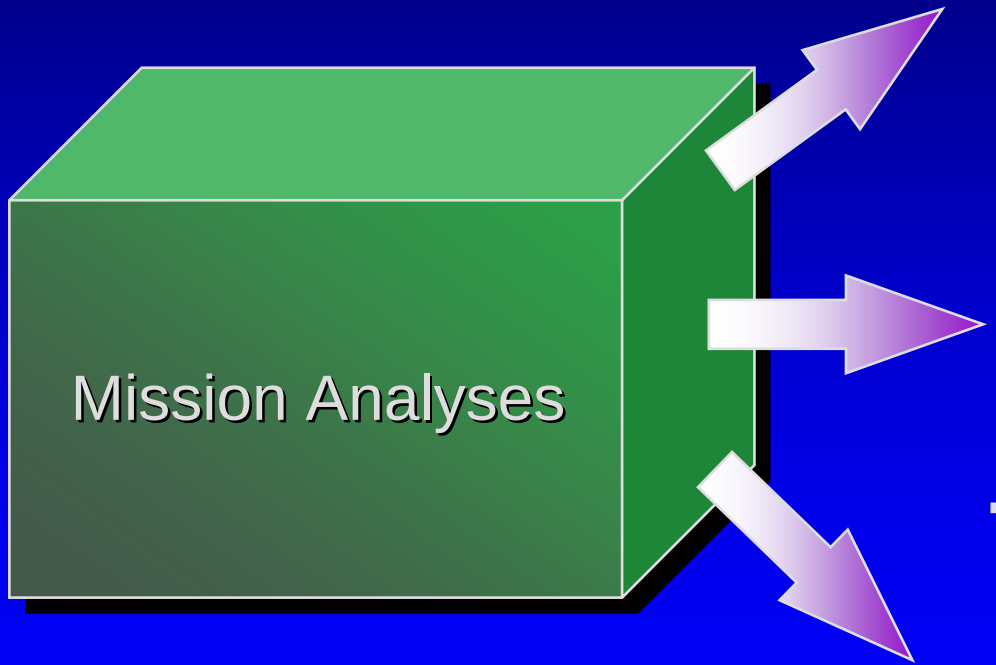
Cassini Mission's FSAR / SER Comparison



On to the discussion

INSRPs: Better Cheaper Faster

Three Separate Approval Processes

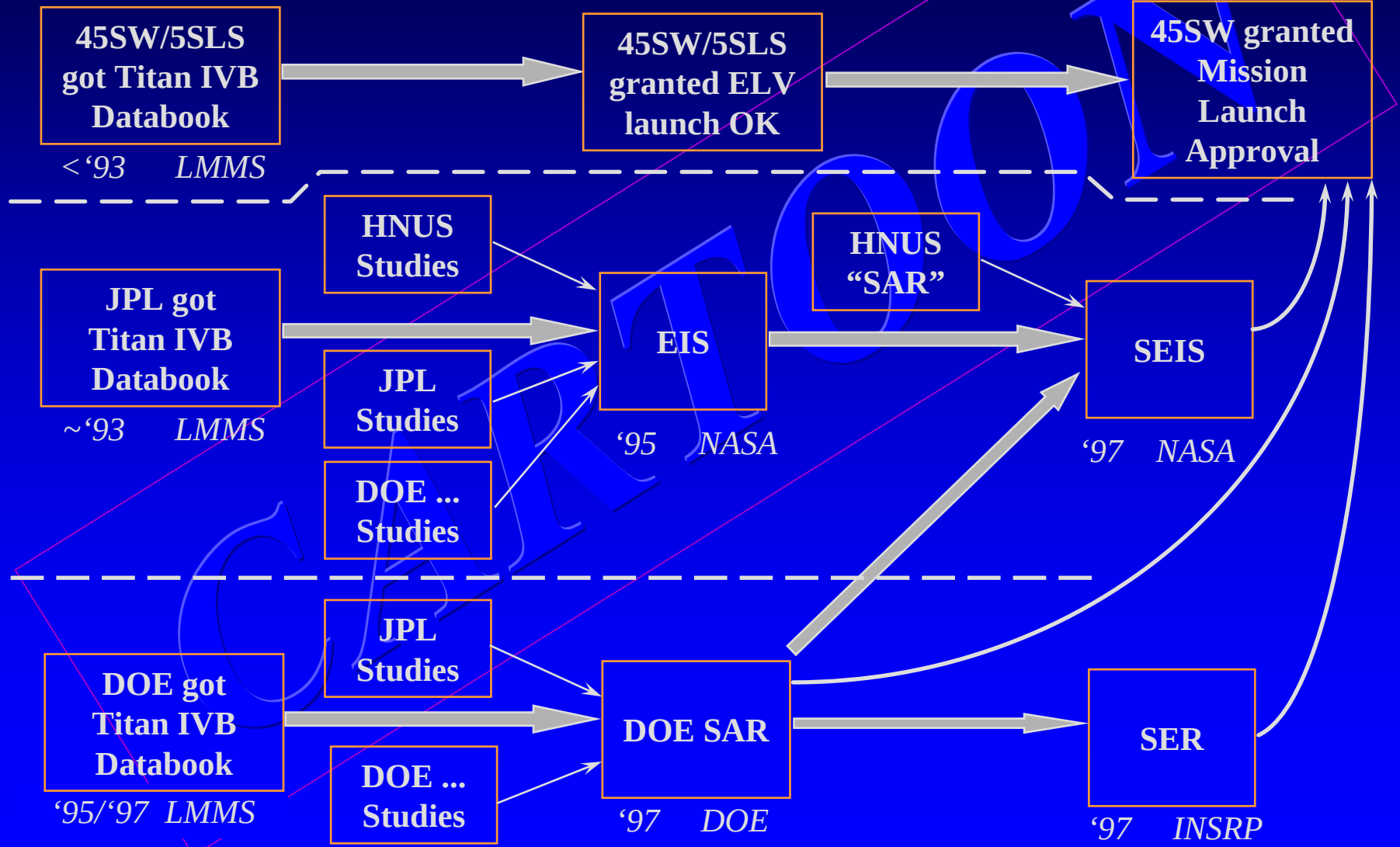


Range Approval

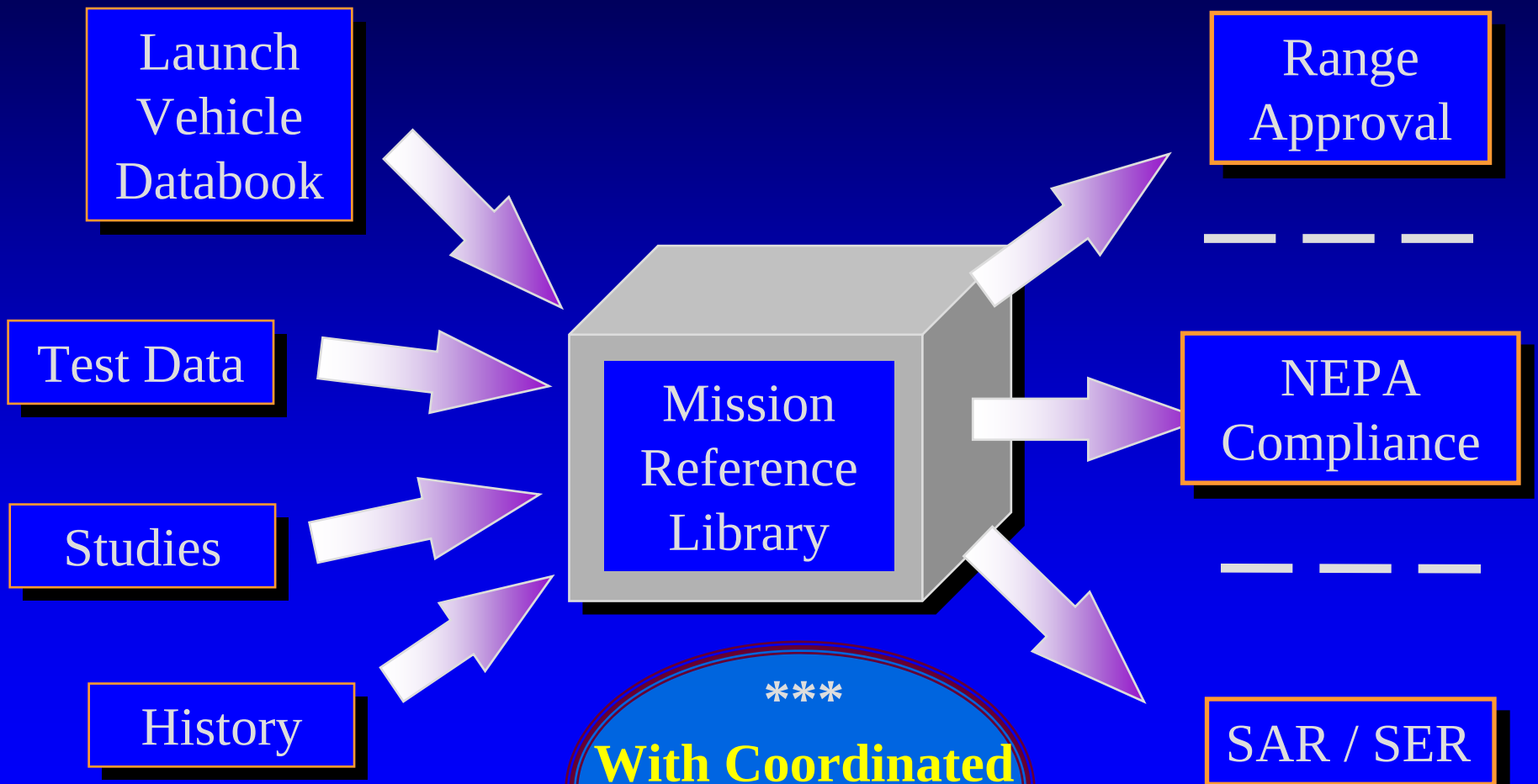
National Environmental Policy Act (NEPA) Compliance

Nuclear Launch Safety Approval

What Cassini Process Produced



What An Approval Process Could Be



Simplified INSRP with Mars '01

- The Mars Surveyor 2001 mission was very similar to Mars Pathfinder mission. Similar launch vehicle, same launch site, similar nuclear components. Maximize reuse of Pathfinder SER.
- MS01 INSRP planned only to:
  - Review Mars Pathfinder SER for items of concern
  - Analyse mission differences to determine risk delta
    (i.e.; Delta rocket variant, weather, upper stage)
  - Review Program Documentation for consistency
- Mars Pathfinder INSRP found only three ways to penetrate the LWRHUs in Delta II accident scenarios:
  - burning solid propellant chunks that land close to an LWRHU;
  - a hardover turn impacting surface nose-down subjecting the LWRHUs to severe crushing followed shortly by a solid propellant explosion;
  - fragments of the highest velocity that manage to slice edge-wise into the LWRHUs edge-on.

Future INSRPs

- Start early to quantify risk drivers
- Don’t analyze risk drivers which don’t show up on final outputs

  (i.e.: down 2 orders of magnitude)
- Don’t analyze risk drivers which even when summed, which are below a threshold of 10^{-8} and/or 1 latent cancer fatality
- Use existing verified tools, models, software and analyses as much as possible

Bottom Line

- The goal of an INSRP is designed to help the decision makers better understand and become more confident in knowing the bounds of the risk introduced due to the use of nuclear materials in space.

- Together, we can do that!

Mission Success Starts with Safety!